Wednesday, May 13
Facility-specific Workshops

APS Workshop 10
Application of Synchrotron X-ray Scattering Techniques to Nuclear Materials

Location: Bldg. 401, Room A5000

Organizers: Don Brown (Los Alamos National Laboratory) and Maria Okuniewski (Idaho National Laboratory)

The heyday of research into nuclear energy materials predated the modern model of the national user facility in the United States, which essentially was pioneered at Intense Pulsed Neutron Source at Argonne National Laboratory in the 1980s. As a result, many of the advanced characterization techniques that have been developed at neutron and synchrotron x-ray sources have not been brought to bear on nuclear materials.

The recent renewed interest in nuclear power, spurred by increased energy costs and concerns about climate change, has meant a resurgence in nuclear materials research, including work at user facilities. However, barriers to the study of naturally radioactive and activated materials still exist, in particular at synchrotron sources, which often do not have the infrastructure to deal with radioactive material that neutron sources inherently possess. The purpose of this proposed workshop is to gather those scientists currently utilizing the APS to study nuclear materials, as well as scientists whose programs could benefit from the advanced tools available at the APS.

The workshop will begin with several talks about cutting-edge nuclear material science to expose non-APS users to the possibilities for this type of work. It will conclude with a discussion of the current policies that govern the study of nuclear materials at the APS, including design of containment, shipping and local transport, sample handling, and completion of the experiment. Here again, participants who are not APS users will add valuable input as they can comment on best practices at universities and other government laboratories. The goal of this workshop is to produce a white paper compiling the expressed needs of the user community regarding radioactive sample handling at the APS and recommendations about how to accommodate those needs.

1:30 – 1:40	Welcome & Introductory Remarks
1:40 – 2:10	Jim Stubbins (University of Illinois Urbana-Champaign) *Analysis of Nuclear Fuels, Cladding, and Structural Materials*
2:10 – 2:40	Meimei Li (Argonne National Laboratory) *Synchrotron Radiation Characterization of Materials for Nuclear Energy Applications*
2:40 – 3:10	Mohamed Elbakhshwan (Brookhaven National Laboratory) *Synchrotron X-ray Diffraction of Nuclear Materials*
3:10 – 3:20	Break
3:30 – 3:50	APS Radiation Safety Officer
3:50 – 4:50	Panel Discussion
4:50	Wrap Up

WK10

Analysis of Nuclear Fuels, Cladding and Structural Materials

James Stubbins

University of Illinois Urbana-Champaign, Urbana, IL 61801

The APS has provided substantial new understanding of the bulk effects that govern the performance of materials for nuclear applications. Much of this understanding is due to the fact that prior to very bright light sources, the performance of materials for nuclear application was determined on pre- and post-irradiated samples where only a "before and after" picture could be obtained. Current work with the APS has provided the opportunity to understand the active processes involved during the deformation of metallic alloys, which were previously not known. In particular, the role of various strengthening mechanisms was not fully characterized or appreciated. In this talk, the effects of various strengthening mechanism on nuclear materials performance will be discussed with particular attention to the new understanding of dynamic deformation processes.

WK10

Synchrotron Radiation Characterization of Materials for Nuclear Energy Applications

Meimei Li

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The use of synchrotron radiation offers new opportunities to advance the fundamental understanding of nuclear reactor materials in extreme conditions of irradiation, tempeature, stress and corrosion. This presentation will highlight recent studies using synchrotron x-ray scattering, spectroscopy and imaging techniques to understand the dynamic behavior of nuclear reactor materials and radiation damage over a wide range of lengh scales. The presentation will also discuss a rcently-developed new capability for *in situ* characterization of irradiated specimens under thermal-mechanical loading using combined techniques of far-field high-energy diffraction microscopy (ff-HEDM)/ tomography/wide-angle x-ray scattering (WAXS)/small-angle x-ray scattering (SAXS). The containment design for safe handling of an irradiated specimen at an open beamline at the APS will also be discussed.

WK10

Synchrotron X-ray Diffraction of Nuclear Materials

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Structural materials for nuclear energy systems are required to withstand radiation and corrosion at high pressure and temperature during reactor operation. Zirconium alloys used for cladding experience corrosion reactions with the coolant as well as the fuel during normal and accident conditions. Austenitic stainless steels, such as 304 and 347, are frequently used for core internals such as core barrels, bolts and support plates. Ferritic-martensitic steels such as T91 and HT9 are being considered as structural materials in advanced nuclear reactors. Exposure to radiation in a nuclear reactor can cause changes in the microstructure of the zirconium alloys or steels that can lead to brittle fracture, fatigue or irradiation-assisted stress-corrosion cracking. Radiation induced segregation can make the material prone to phase-transformations and the creation of new phases. In addition, the accumulation of defects (vacancy clusters) or helium can lead to void formation and swelling.

Synchrotron radiation sources can play an essential role in providing quantitative characterization of the atomic structure of complex materials; not just carefully prepared ideal systems, but materials that are actually used in nuclear reactors. The presentation will focus on the early oxidation states of fuel cladding alloys and the characterization of irradiated materials that was performed at the new state-of-the-art National Synchrotron Light Source II (NSLS II).

First, a sample environment was developed to perform *in situ* x-ray diffraction and x-ray fluorescence to understand the behavior of zirconium alloys under high pressure and temperature steam environment. Second, a robot has been developed at the X-ray Powder Diffraction (XPD) Beamline to automatically acquire high-resolution x-ray diffraction data, high energy (high Q) data for Pair Distribution Function Analysis, and small-angle x-ray scattering data for large number of samples of reactor pressure vessel steels or structural materials with varying chemistries, grain sizes, cold-work conditions and irradiation conditions. This tool provides safe, unmanned manipulation of relatively large numbers of radioactive samples for statistically representative, high-throughput measurements.